Institute of Physics Publishing | Physics in Medicine and Biology
Phys. Med. Biol. **50** (2005) 1313–1325 | doi:10.1088/0031-9155/50/6/018

Two-dimensional waveform analysis in MR elastography of skeletal muscles

Sebastian Papazoglou[1], Jürgen Braun[2], Uwe Hamhaber[2] and Ingolf Sack[1]

[1] Institute of Radiology, Charité—University Medicine Berlin, Humboldt University Berlin, Berlin, Germany
[2] Institute of Medical Informatics, Charité—University Medicine Berlin, Free University Berlin, Berlin, Germany

E-mail: ingolf.sack@charite.de

Received 13 August 2004, in final form 10 December 2004
Published 2 March 2005
Online at stacks.iop.org/PMB/50/1313

Abstract

A method for direct determination of anisotropic elastic coefficients using two-dimensional shear wave patterns is introduced. Thereby, the symmetry of the wave patterns is approximated by a squared elliptic equation yielding an explicit relation between waveform and elasticity. The method is used to analyse MR elastography wave images of the biceps acquired by a continuous harmonic excitation at the distal tendon of the muscle. Typically *V*-shaped wave patterns were observed in this type of tissue, which could be well reproduced by the proposed elliptic approximation of the waveform assuming incompressibility and a transverse isotropic model of elasticity. Without additional experiments, the analysis of straightness, slope and interferences of the wave fronts enabled us to deduce two Young's moduli and one shear modulus, which fully describe the anisotropy of the elasticity of muscles. The results suggest strong anisotropy of the living human biceps causing a shear wave speed parallel to the muscle fibres that is approximately four times faster than the perpendicular shear wave speed.

Introduction

The determination of mechanical properties of human skeletal muscles is of principal interest in medicine and biomechanics (Fung 1993, Humphrey 2002). For this reason elastography techniques have been employed to non-invasively designate mechanical parameters of skeletal muscles under rest or activation (Levinson *et al* 1995, Gao *et al* 1996, Dresner *et al* 2001, Nightingale *et al* 2002, Sack *et al* 2002, Gennisson *et al* 2003, Uffmann *et al* 2004). In dynamic elastography, low frequency shear waves are employed to map the shear modulus in terms of wavelengths of tissue-displacement fields under varying muscle loads (Levinson *et al* 1995, Dresner *et al* 2001, Basford *et al* 2002, Heers *et al* 2003). While in ultrasound